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ABSTRACT

This researcher investigated two problems: (1) the accuracy and validity of instruments which measure Piagetian levels of thought; and (2) the need for more detailed models of concrete and formal operational structures, both as they develop and consolidate, and in their most highly developed state. Several tasks such as the Piagetian correlations task are presented to demonstrate that the character or value of a task variable may create the discrepancy in performance, rather than the specific content area of a problem. It appears from these examples that it is important to analyze a task prior to presenting it. It is also indicated that the noise from instrumental errors may be larger than the noise from sampling errors. The remainder of the paper discusses the need for a more detailed conceptualization of formal thought. If it can be represented in terms of various operations and schema, it needs to be known which schema develop earliest, which depend hierarchically on the development of others, and at what level of development each must be before consolidation takes place. (HM)

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Methodological Issues in Research: The Need for Improved Instrumentation and Model Building

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INTRODUCTION

Over the past decade, many researchers, particularly within the area of science education, have begun to probe the Piagetian model of operational thought from concrete through formal operations. In most cases, the basic tool or instrumentation of investigators has been the tasks described in The Growth of Logical Thinking (Inhelder and Piaget) and similar works translated from the French originals. While Piaget relied heavily on long clinical interviews for his data, the American fascination has been with standardizing and minimizing the time required for administration of the tasks. Of great interest have been attempts to develop a written task which could distinguish the presence of formal vs. concrete operational abilities within individuals.

In these efforts, not enough attention has been paid to two major problems. One is the accuracy and validity of the measuring instruments. The second is a need for more finely detailed models of concrete and formal operational structures, both as they develop and consolidate and in their most highly sophisticated state.

INSTRUMENTATION

A basic problem in measurement is the choice of an appropriate, valid and efficient instrument. To quote Nunnally:

> A case could be made that the major problem in psychology is that of measurement. There is no end of theories, but the theories are populated with terms (hypothesized attributes) which presently cannot be adequately measured; consequently the theories go untested. .....In fact it seems that major advances in psychology and probably in all sciences, are preceded by breakthroughs in measurement methods. This is attested to by the flood of research following the development of intelligence tests.... Scientific results inevitably are reported in terms of functional relations among measured variables, and the science of psychology will progress neither slower nor faster than it becomes possible to measure important variables. (Nunnally)

This problem is particularly thorny when dealing with mental structures. While we as science-oriented practitioners would reject the idea of measuring football fields with micrometers, or lens apertures with meter sticks, in both

cases the instruments validly measure lengths (albeit inefficiently). In measuring mental attributes, our task is complicated by the often nebulous nature of the variable that is being measured. One cannot always be certain that two instruments measure the same attribute. Examination of correlations are of limited help since two instruments may be highly correlated because they measure the same thing, or because they measure two attributes that are causally related. In many cases one must rely on the opinion of an appropriate group of 'experts' that the test indeed measures what it seems to.

The Physical Scientist

Consider the physical scientist and the instrumentation he/she uses. As experimentation has become more sophisticated and the need for more precise data has emerged, the technical community has responded with major advances in equipment to measure the attributes in question. Electronic methods of signal processing have enhanced our ability to extract the signals of interest from a background of interference from many sources. In most experiments, the signal-to-noise ratio remains a crucial measure of the sensitivity of instruments (Figure 1).

A further advantage for the physical scientist is the fact that the objects of measurement do not have complex personalities as do humans. Electrons don't perform differently if measured before or after lunch. While they may undergo catastrophic breakups with nuclei, the after effects are not those of the dissolution of a human relationship. Best of all, one need not concern oneself with sampling error arising from choosing one electron rather than another, nor with protecting the confidentiality of each one. Imagine waiting for signed releases from billions of electrons! (Figure 2)

The Behavioral Scientist

With people, of course, one must deal with numerous influences affecting performance, along with the problems of smaller samples and the possible changing

of an attribute with time. In general, one would like to measure changes in attributes in order to describe a course of development. However, the nature of sampling introduces an uncertainty in our measurements and acts as noise masking our signal of interest. One way to reduce the effect of such "noise" is to increase the sample size--a brilliant idea in principal, but often impractical at least within the lifetime of most graduate students, who, as is well known, do much of the research in science education.

But beyond this error inherent in experimentation due to subject sampling is the uncertainty introduced by the instrumental apparatus due to "item sampling"--in this case, the test questions or tasks. If test instruments are imprecise in their measures of an attribute, either in structure or in the subjectivity of scoring protocols, then one has introduced a source of possible error ("imprecision") which may be larger than accounted-for statistical errors. (Figure 3)

SOURCES OF ERROR

In the past, numerous explanations have arisen to account for inconsistency of performance by subjects on tasks of logically equivalent content which preportedly measured the same scheme. Explanations which have been proposed include Piagetian notions of decalage (Piaget and Inhelder), Neo-Piagetian formulations such as differing degrees of M-space (Pascual-Leone) and arguments of competency versus performance via performance factors (Flavell; Wohlwill) (i.e. the content and character of the task). What the accompanying papers (Sindhikara, Brendzel, Cheu) will demonstrate is that it is the type and character of the variables used which create the discrepancy in performance, rather than the specific content area of the problem. To develop this particular point, let us examine a few of the instruments frequently used to assess Piagetian operational levels of thought.

Consider, for example, the Piagetian task of correlations (Figure 4). In the original task, subjects were presented with cards of persons with two colors

of hair and two colors of eyes. Note carefully that this situation provides a relationship between familiar variables with concrete values. Note further that the colors are multivalued, but discrete (if we ignore shades), and that no one value of either variable is necessarily 'better,' or, more salient. Finally, it should be noted that the situation may be too familiar since one has a preconceived notion that dark hair and dark eyes more often occur together.

Contrast this with a logically equivalent task using the baseball team having test bats and standard bats and records are kept on how many games are won or lost using each kind of bats. (Figure 5) Now one sees two dichotomous variables, both with heavily value-laden choices. The variables are less concrete than before but still familiar. Again there may be a preconceived relationship (Cheu).

Other problems could be devised using variables that were truly dichotomous, multivalued, or continuous but artificially dichotomized. They might be neutral or value-laden; familiar or unfamiliar, abstract or concrete; meaningful or nonsensical. Other possible dimensions are left to the reader as an exercise.

Another example of a task where the nature of the variable exerts an influence is the frequently used "Mr. Tall" task (Karplus). As given, the task involves linear proportion using familiar objects (paper clips and buttons) in unfamiliar roles (measurement). The ratio used is complex in that it does not reduce to the form 1:n where n is an integer (Figure 6).

Contrast this to similar tasks (Abramowitz, Brendzel) which may involve area or volume or numerical proportions (e.g. carpets or recipes), unfamiliar objects in familiar roles (e.g. bottles as measuring devices), and simple ratios (i.e., of the form 1:n where n is an integer).

As a final example, consider a task of concrete operations such as classification or seriation. In this the subject is asked to recognize subsets of a whole and recognize that the whole is bigger than either subset. For example,

EXAMPLE OF
SIGNAL PROCESSING

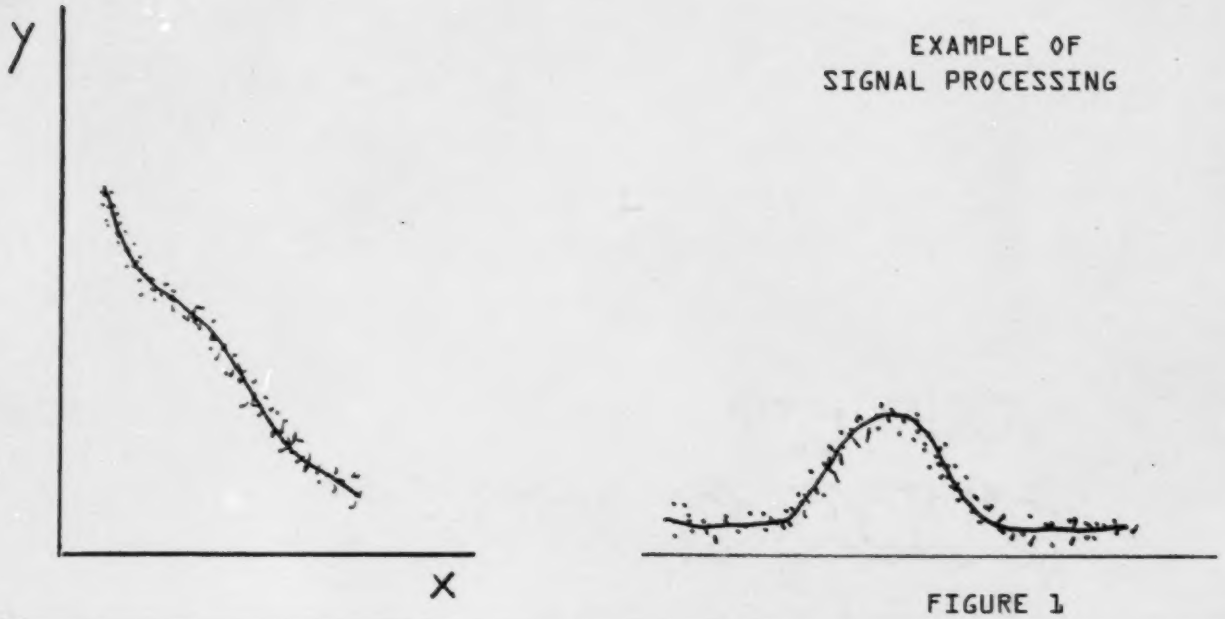
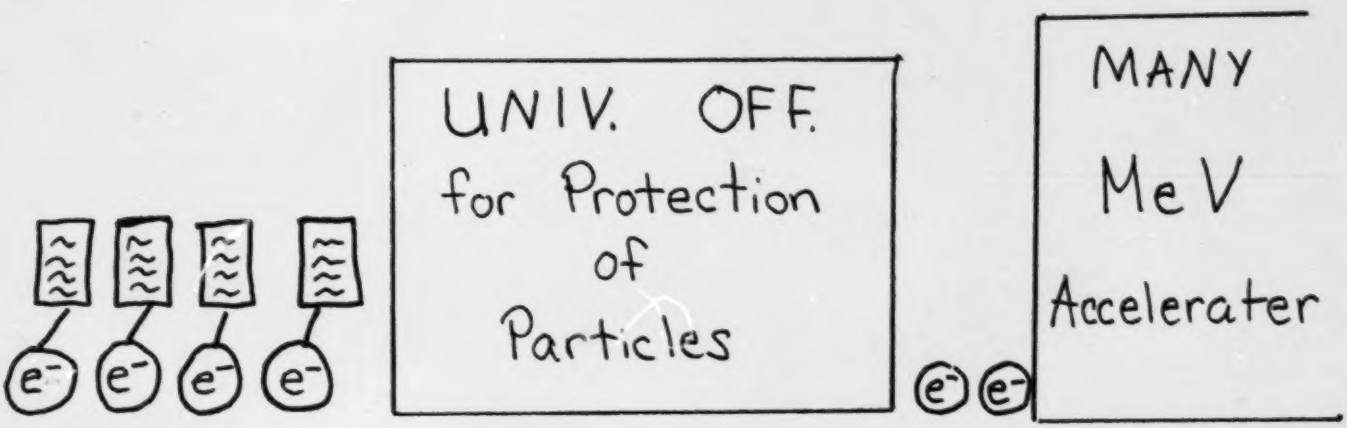


FIGURE 1



PROTECTION OF SUBJECTS FIGURE 2

UNCERTAINTY IN INSTRUMENT AND SAMPLE FIGURE 3

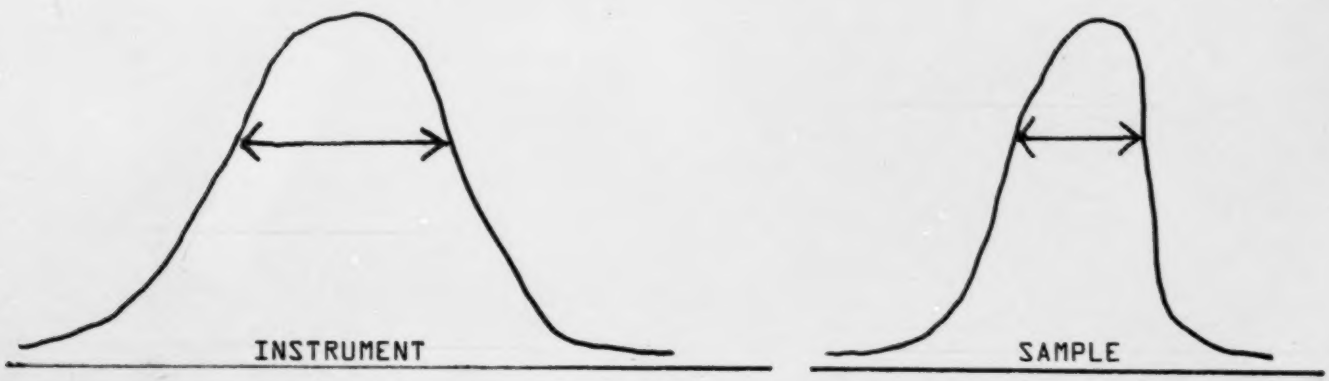


FIGURE 4

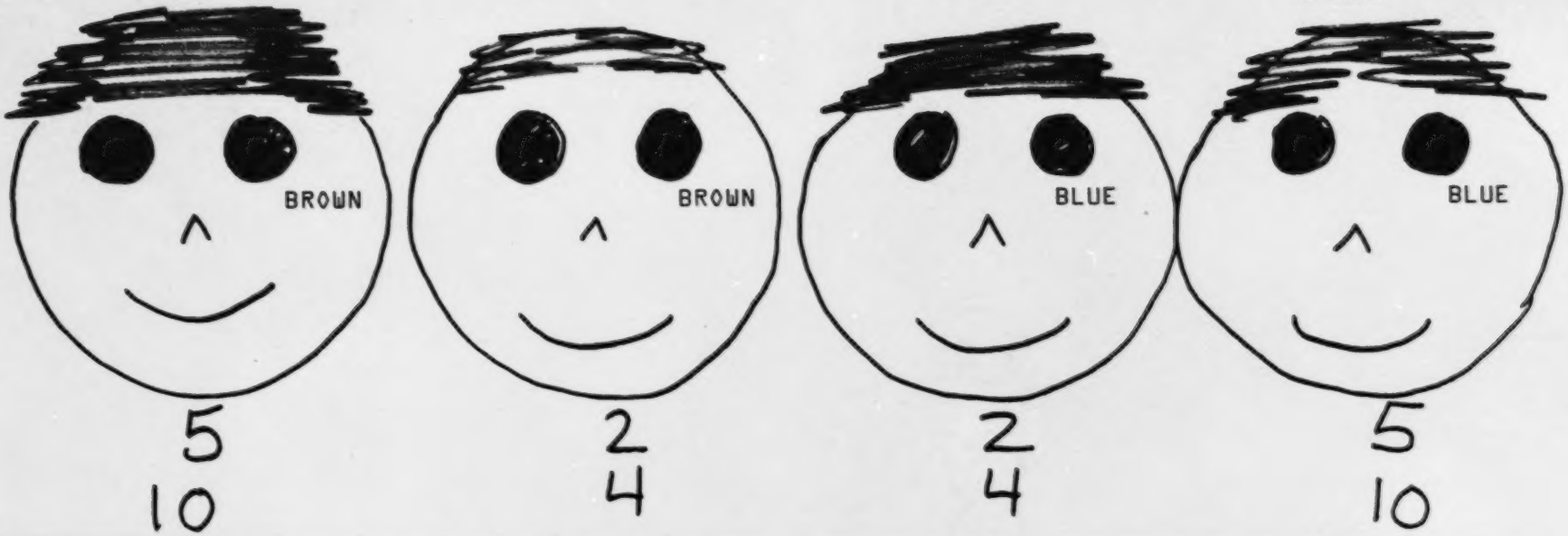
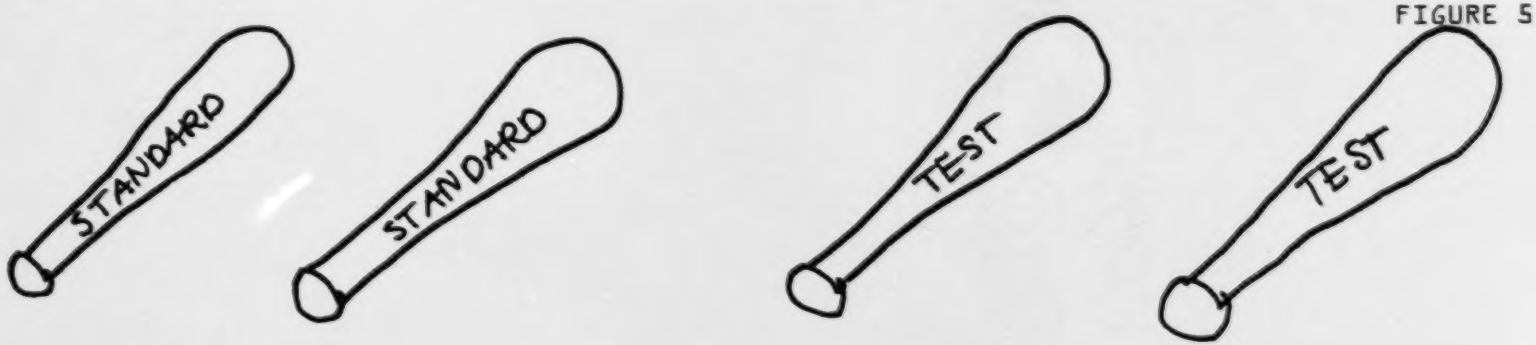


FIGURE 5



WIN	LOSE	WIN	LOSE
5	2	2	5
10	4	4	10

given a set of candies (B), both chocolates (A) and peppermints (A') one would ask the child whether there were more chocolates or candies. While it would appear one can either correctly solve this problem or can't, it turns out (Sindhikara) the use of small numbers and large numbers not only influences the success rate but the character of the subjects' responses. Other differences can be seen in allowing set A=set A' in size or having them different, and in hiding some candies from view (Figure 7).

It should be clear from these examples that it is extremely important to analyze a task prior to presenting it. In particular, one must be certain that the particular values of variables chosen do not allow a problem which should require a formal operational solution to be succinctly and accurately solved by concrete strategies.

Since the nature of the instrument used in the measurement may have strong effects on the measurement, a situation results where the "noise" from the instrument may in fact be larger than the "noise" from the sample. The possible uncertainty in measurement due to sampling error is taken into account through statistical tests of significance. But the uncertainly introduced by an imprecise measuring device is at least as important as subject sampling error. It may be, in fact that sampling uncertainty is quite small compared to instrumental errors.

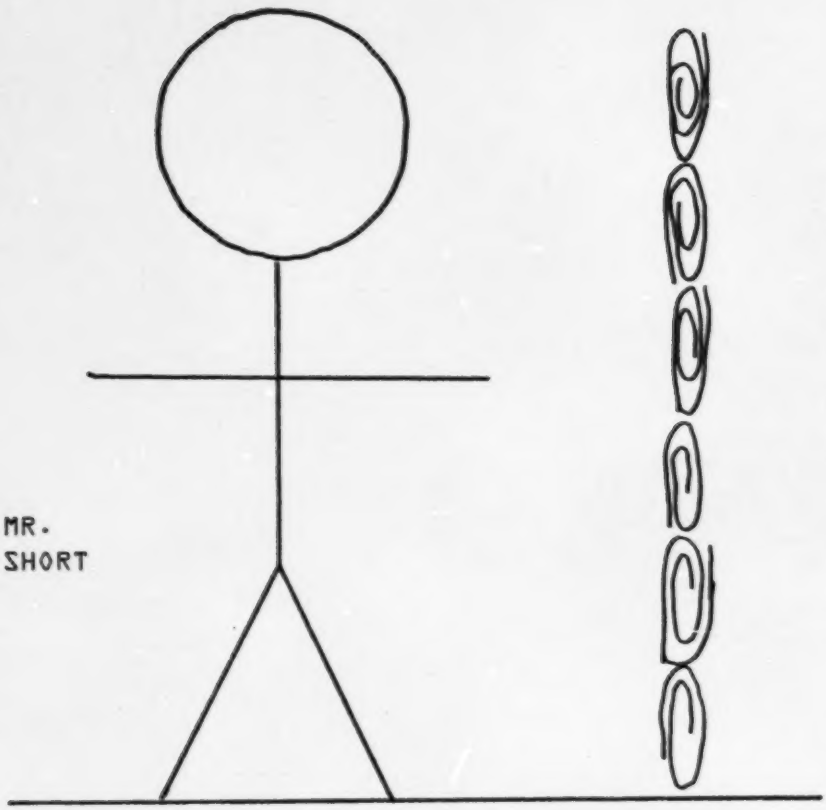
THEORETICAL SHORTCOMINGS

Another point which I believe must be addressed is the need for better theoretical formulations. It is difficult to develop an appropriate instrument if there is no agreement on what it is that is being measured. Theories must be presented which make solidly testable predictions, which can be empirically and demonstrably tested.

Earlier the Piagetian and Neo-Piagetian models of cognitive thought were mentioned. These, I believe, are analogous to the early twentieth century Bohr model of the atom. (Figure 8) Let us briefly develop that analogy. In the Bohr model, electrons in an atom are being excited to higher energy states. Electrons must exist in one state or another and transitions are abrupt from one level to another. Each level is at a higher energy than the one below. Only an input of the right amount of energy can cause a transition upward. If one refines the model slightly, different orbitals appear within a given level, and each of these may have slightly different energies (Figure 9). If one includes other effects due to the spin of the electron, one develops smaller differences in energy and a hierarchy of energies and levels, and a series of allowed transitions.

In the Piagetian model (Figure 10), people, like the electrons, are at various cognitive levels. As one moves upward from a sensorimotor level, there are increasing numbers of sublevels, corresponding to the differentiation of abilities or schema within each level. Yet, in general, one might classify a person, in regards to a particular schema or set of schema, as being "concrete" or "formal." Persons either have or do not have a particular schema at a particular level and with time, transitions would be observed from one level to another. Only the right kind of experiences in the environment can cause the disequilibration necessary to promote transition upward. Naturally, we are interested in having these "excited states" of people to become stable, unlike our electrons, so that the concrete or formal operational scheme becomes accessible in all contexts.

Perhaps an even better analogy is the filling of atomic shells in an atom (Figure 11). Once a lower shell is completely filled, electrons begin filling upper energy levels and sublevels. On occasion, in the third and fourth level, we find higher orbitals containing electrons, even though lower ones are not yet filled.



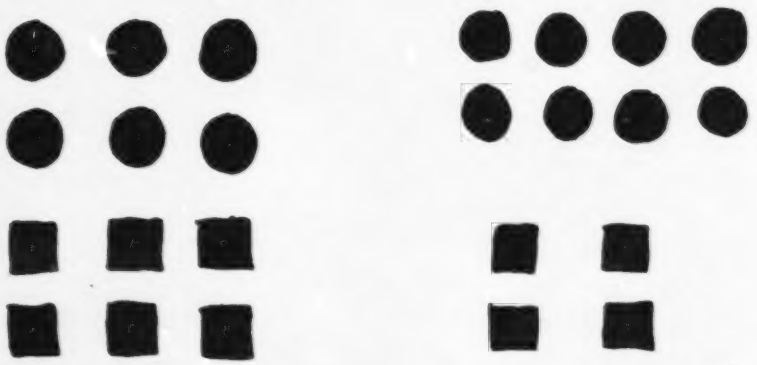
MR. SHORT IS 4 BUTTONS TALL.

MR. TALL IS 6 BUTTONS TALL.

HOW TALL IS MR. TALL IN PAPER CLIPS?

FIGURE 6 "MR. TALL TYPE TASK"

FIGURE 7 CLASS INCLUSION



$A = A'$ $A > A'$

HIDDEN OBJECTS

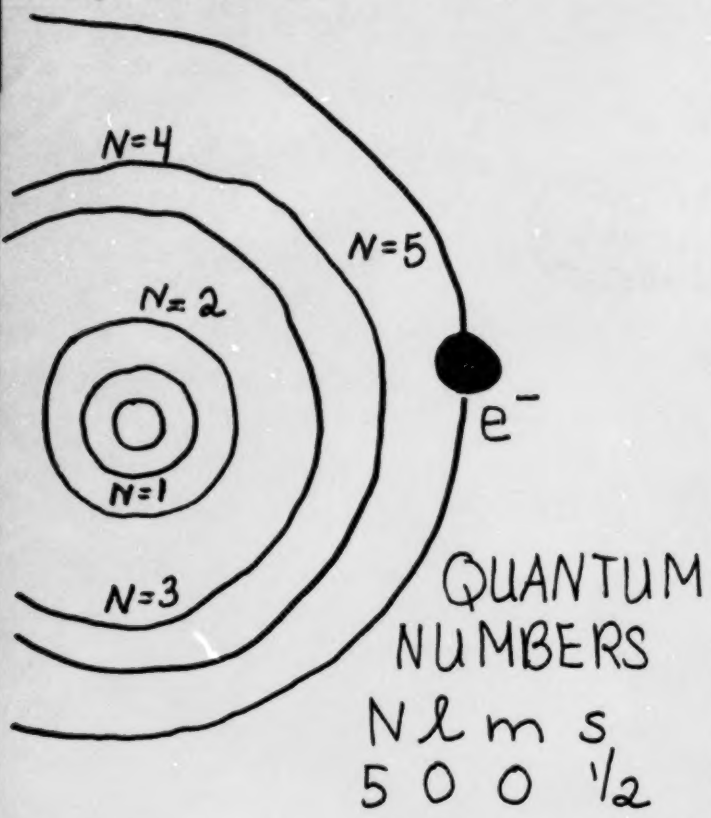


FIGURE 8: BOHR MODEL

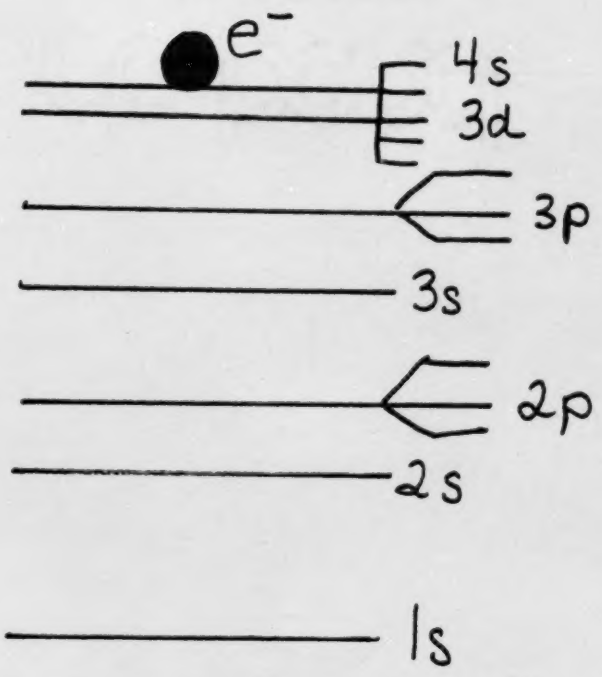


FIGURE 9: ENERGY LEVELS

PIAGETIAN
QUANTUM NO.

COMB.	PROP.	PROB ...
F	C	C

FIGURE 10

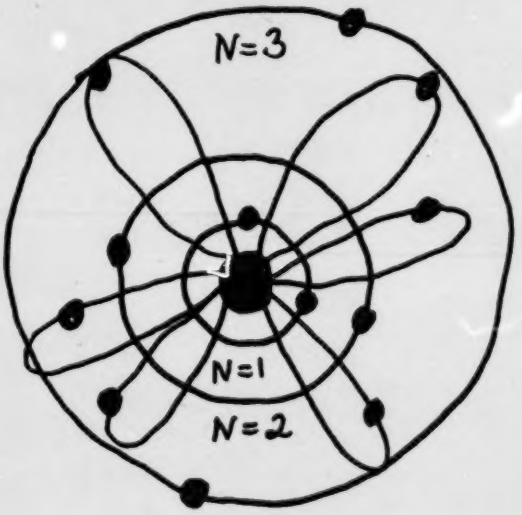


FIGURE 11: SHELL MODEL

The Piagetian analogy is the addition of experiences until a person consolidates, or equilibrates at a particular level. The filled shells are stages fully developed in the individual. Frequently individuals show aspects of higher thought in particular schema. As more and more of these schema are completed, the higher order abilities become more and more consolidated (available across most situations). Those with completed shells will be more stable, as are atomic elements with filled shells. Thus it takes a great deal of energy to unbalance either the electrons or the people.

Returning to the Bohr analogy, too little is known about the intrinsic structure of higher "orbitals," namely formal operations. What is the hierarchy of schema, if any? How do these tie together? Perhaps most important for education: what experiences are necessary to promote transition and develop a stable state of the schema necessary to succeed in science and other courses?

Ultimately, it may be necessary to reformulate entirely our view of cognition. Much as the quantum mechanical description of the atom has supplanted the Bohr model, we may soon see a new formulation to replace this first-order heuristic model of Jean Piaget's.

REFERENCES

Abramowitz, Susan, Adolescent Understanding of Proportionality: The Effect of Task Characteristics, ERIC ED 111-688 (1976).

Brendzel, Sharon, A Study on Proportional Reasoning, NARST meeting, 1978.

Cheu, Janey, Criteria for Assessing Correlational Ability, NARST meeting, 1978.

Flavell, J.H. and Wohlwill, J.F., Formal and Functional Aspects of Cognitive Development, Studies in Cognitive Development: Essays in Honor of Jean Piaget, Oxford University Press (1969).

Inhelder, B. and Piaget, J. The Growth of Logical Thinking from Childhood to Adolescence, New York: Basic Books (1958).

Karplus, R. and Peterson, R.W., Intellectual Development beyond Elementary School. II Ratio: a Survey. School Science and Mathematics, 70. (1970), 813-820.

Nunnally, Jum, Psychometric Theory, McGraw Hill (1967), 5.

Pascual-Leone, J., A Mathematical Model for the Transition in Piaget's Developmental Stages. Acta Psychologica, 32 (1970) 301-349.

Piaget, J. and Inhelder, B., The Psychology of the Child, New York: Basic Books (1969).

Sindhikara, J., Analysis of Class Inclusion Response Identification Types, NARST meeting, 1978.